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FIELD OF THE INVENTION

The present invention relates to alertness monitoring for drivers of motor vehicles.

BACKGROUND OF THE INVENTION

The following patents are believed to represent the current state of the art:

U.S. Patents 3,227,998; 3,631,446; 3,654,599; 3,935,830; 3,980,999; 4,007,357; 4,017,843; 4,104,621; 4,450,438; 4,463,347; 4,496,938; 4,509,040; 4,518,954; 4,564,833; 4,565,997; 4,581,607; 4,586,032; 4,594,583; 4,604,611; 4,611,199; 4,673,913; 4,794,536; 4,853,672; 4,984,646; 4,996,657; 5,057,834; 5,097,917; 5,282,135; 5,465,079; 5,488,353; 5,548,273; 5,568,127; 5,570,087; 5,570,698; 5,585,785; 5,675,313; 5,684,455; 5,684,462; 5,689,241; 5,709,281; 5,714,925; 5,717,606; 5,729,619; 5,745,031; 5,765,116; 5,786,765; 5,795,306; 5,798,695; 5,805,079; 5,805,720; 5,813,993; 5,815,070; 5,821,860; 5,835,008; 5,835,028; 5,847,648; 5,850,193; 5,867,587; 5,900,819; 5,917,415; 5,923,263; 5,925,082; 5,939,989; 5,942,979; 5,969,616; 5,982,287; 6,023,227; 6,061,610; 6,064,301; 6,067,020; 6,087,941; 6,087,943; 6,091,334; 6,097,286; 6,097,295; 6,172,610.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved methodology and system for monitoring the alertness of drivers of motor vehicles.

There is thus provided in accordance with a preferred embodiment of the present invention a methodology for determining the alertness of a driver of a motor vehicle including:

sensing at least one first movement characteristic of at least a first part of a motor vehicle;

sensing at least one second movement characteristic of at least a second part of the motor vehicle;

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employing at least one time relationship between the at least one first movement characteristic and the at least one second movement characteristic in order to sense and to distinguish between driver initiated movements and non-driver initiated movements; and

determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

There is also provided in accordance with a preferred embodiment of the present invention, a methodology for determining the alertness of a driver of a motor vehicle including:

employing at least one time relationship between at least one first movement characteristic of at least a first part of a motor vehicle and at least one second movement characteristic of at least a second part of the motor vehicle in order to sense and to distinguish between driver initiated movements and non-driver initiated movements; and

determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

There is additionally provided in accordance with a preferred embodiment of the present invention a methodology for determining the alertness of a driver of a motor vehicle including:

sensing at least one first movement characteristic of at least a first part of a motor vehicle;

sensing at least one second movement characteristic of at least a second part of a motor vehicle; and

employing the at least one first movement characteristic and the at least one second movement characteristic in order to determine the alertness of the driver of the motor vehicle.

There is further provided in accordance with a preferred embodiment of the present invention a methodology for determining the alertness of a driver of a motor vehicle including:

sensing at least one first movement characteristic of at least a first part of

a motor vehicle;

sensing at least one second movement characteristic of at least a second part of the motor vehicle;

employing the at least one first movement characteristic and the at least one second movement characteristic in order to sense driver initiated movements; and

determining the alertness of the driver of the motor vehicle based at least partially on the sensed driver initiated movements.

There is additionally provided in accordance with a preferred embodiment of the present invention a system for determining the alertness of a driver of a motor vehicle including:

a first sensor sensing at least one first movement characteristic of at least a first part of a motor vehicle;

a second sensor sensing at least one second movement characteristic of at least a second part of the motor vehicle;

a distinguisher, employing at least one time relationship between the at least one first movement characteristic and the at least one second movement characteristic in order to sense and to distinguish between driver initiated movements and non-driver initiated movements; and

an alertness determiner, determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

There is further provided in accordance with a preferred embodiment of the present invention a system for determining the alertness of a driver of a motor vehicle including:

a distinguisher, employing at least one time relationship between at least one first movement characteristic of at least a first part of a motor vehicle and at least one second movement characteristic of at least a second part of the motor vehicle in order to sense and to distinguish between driver initiated movements and non-driver initiated movements; and

an alertness determiner, determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

There is still further provided in accordance with a preferred embodiment of the present invention a system for determining the alertness of a driver of a motor vehicle including:

a first sensor, sensing at least one first movement characteristic of at least a first part of a motor vehicle;

a second sensor, sensing at least one second movement characteristic of at least a second part of a motor vehicle; and

a distinguisher, employing the at least one first movement characteristic and the at least one second movement characteristic in order to determine the alertness of the driver of the motor vehicle.

There is yet further in accordance with a preferred embodiment of the present invention provided a system for determining the alertness of a driver of a motor vehicle including:

a first sensor, sensing at least one first movement characteristic of at least a first part of a motor vehicle;

a second sensor, sensing at least one second movement characteristic of at least a second part of the motor vehicle;

a distinguisher, employing the at least one first movement characteristic and the at least one second movement characteristic in order to sense driver initiated movements; and

an alertness determiner, determining the alertness of the driver of the motor vehicle based at least partially on the sensed driver initiated movements.

There is still further provided in accordance with a preferred embodiment of the present invention a methodology for determining the alertness of a driver of a motor vehicle including:

sensing at least one characteristic of driver initiated movements of at least one part of a motor vehicle;

sensing at least one characteristic of non-driver initiated movements of at least one part of a motor vehicle; and

determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

There is additionally provided in accordance with a preferred embodiment of the present invention a system for determining the alertness of a driver of a motor vehicle including:

a driver initiated movement sensor, sensing at least one characteristic of driver initiated movements of at least one part of a motor vehicle;

a non-driver initiated movement sensor, sensing at least one characteristic of non-driver initiated movements of at least one part of a motor vehicle; and

a determiner, determining the alertness of the driver of the motor vehicle based on at least one relationship between the driver initiated movements and the non-driver initiated movements.

Preferably, the at least one characteristic of driver initiated movements is extent.

Preferably, the at least one characteristics of non-driver initiated movements is extent.

In accordance with a preferred embodiment of the present invention, extent of driver initiated movements includes at least one of:

the integrated magnitude of the driver initiated movements;

the RMS average of the magnitude of the driver initiated movements;

the number of peaks of the driver initiated movements per unit time.

In accordance with a preferred embodiment of the present invention, extent of non-driver initiated movements includes at least one of:

the integrated magnitude of the non-driver initiated movements;

the RMS average of the magnitude of the non-driver initiated movements;

the number of peaks of the non-driver initiated movements per unit time.

Preferably, the sensing at least one characteristic of driver initiated movements of at least one part of a motor vehicle and the sensing at least one characteristic of non-driver initiated movements of at least one part of a motor vehicle include sensing at least one first movement characteristic and sensing at least one second movement characteristic of the motor vehicle.

Preferably, the at least one first movement characteristic includes a steering wheel movement characteristic and the at least one second movement characteristic includes a road wheel movement characteristic.

In accordance with a preferred embodiment of the present invention, the at least one first movement characteristic and the at least one second movement characteristic include movement characteristics of first and second locations along a steering assembly extending from a steering wheel to at least one road wheel of the motor vehicle.

Preferably, the at least one first movement characteristic includes a steering assembly movement characteristic and the at least one second movement characteristic includes a vehicle body movement characteristic.

In accordance with a preferred embodiment of the present invention, the at least one first movement characteristic includes a steering assembly movement characteristic and the at least one second movement characteristic includes a vehicle chassis movement characteristic.

Preferably, the first and second locations are located respectively at or upstream of and at or downstream of a power steering unit forming part of the steering assembly.

In accordance with a preferred embodiment of the present invention, the first location is at a steering wheel forming part of the steering assembly.

Preferably, the at least one first movement characteristic is angular displacement of the steering wheel; and

the at least one second movement characteristic is a steering angle of at least one road wheel.

In accordance with a preferred embodiment of the present invention, the at least one first movement characteristic is displacement; and

the at least one second movement characteristic is displacement.

Alternatively, the at least one first movement characteristic is displacement; and

the at least one second movement characteristic is acceleration in at least one direction.

In a further alternative, the at least one first movement characteristic is

displacement; and

the at least one second movement characteristic is acceleration in at least one direction.

Preferably, determining also employs the speed of the vehicle.

In accordance with a preferred embodiment of the present invention, the driver initiated movement sensor sensing at least one characteristic of driver initiated movements of at least one part of a motor vehicle and the non-driver initiated movement sensor sensing at least one characteristic of non-driver initiated movements of at least one part of a motor vehicle include a first sensor, sensing at least one first movement characteristic and a second sensor sensing at least one second movement characteristic of the motor vehicle.

Preferably, the system also includes a driver alertness alarm, responsive to an alarm from the driver alertness determiner for providing an alarm to a driver deemed not to be sufficiently alert.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Figs. 1A and 1B are simplified pictorial illustrations of a methodology for determining the alertness of a driver of a motor vehicle in accordance with a preferred embodiment of the present invention, respectively illustrating operation when a driver is alert and when a driver is not alert;

Fig. 2 is a simplified pictorial illustration of a system operative to provide the functionality of Figs. 1A and 1B and showing inter alia a steering assembly and part of a chassis of a typical motor vehicle as well as illustrating a plurality of locations where measurements of motion may be made in accordance with a preferred embodiment of the present invention;

Fig. 3A is a simplified flow chart of the functionality of Figs. 1A and 1B in accordance with one preferred embodiment of the present invention;

Fig. 3B is a simplified flow chart of the functionality of Figs. 1A and 1B in accordance with another preferred embodiment of the present invention;

Fig. 3C is a simplified flow chart of the functionality of Figs. 1A and 1B in accordance with yet another preferred embodiment of the present invention;

Fig. 4A is an illustration of the functionality of Figs. 1A and 1B in accordance with one preferred embodiment of the present invention over a first time period corresponding to a first set of driving conditions and driver conditions;

Fig. 4B is an illustration of the functionality of Figs. 1A and 1B in accordance with one preferred embodiment of the present invention over a second time period corresponding to a second set of driving conditions and driver conditions;

Fig. 4C is an illustration of the functionality of Figs. 1A and 1B in accordance with one preferred embodiment of the present invention over a third time period corresponding to a third set of driving conditions and driver conditions;

Fig. 5 is a diagram in the form appearing also in Figs. 1A and 1B, illustrating data points produced in accordance with the present invention from the data appearing in Figs. 4A, 4B and 4C; and

Fig. 6 is a simplified flow chart illustrating application of alertness criteria to driving samples in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Figs. 1A and 1B, which are simplified pictorial illustrations of a system and methodology for determining the alertness of a driver of a motor vehicle in accordance with a preferred embodiment of the present invention, respectively illustrating operation when a driver is alert and when a driver is not alert.

As seen in Figs. 1A and 1B, a determination of the alertness of the driver is made based on a statistical relationship between at least one characteristic of driver initiated movements of at least one part of a motor vehicle and at least one characteristic of non-driver initiated movements of at least one part of a motor vehicle.

A typical driver initiated movement includes controlled movements of the motor vehicle, as for example by the driver turning the steering wheel. A typical non-driver initiated movements of the motor vehicle includes uncontrolled movements of the motor vehicle, as for example by the car encountering an uneven section of the

road, a gust or unbalanced vehicle wheels.

In the preferred embodiment of the invention illustrated in Figs. 1A and 1B, the at least one characteristic of both driver initiated movements and of non-driver initiated movements is extent. The use of the term "extent", when used with "driver initiated motions" and "non-driver initiated motions", is intended to convey measures of such motions. This measure may be derived in one or more different ways.

It is appreciated that alternatively different characteristics or metrics may be employed for driver initiated movements and for non-driver initiated movements.

As will be described hereinbelow, for the purposes of the present invention, extent may be one or more of at least the following parameters for driver initiated movements:

the integrated magnitude of the driver initiated movements;

the RMS average of the magnitude of the driver initiated movements;

the number of peaks of the driver initiated movements per unit time.

Likewise, extent may be one or more of at least the following parameters for non-driver initiated movements:

the integrated magnitude of the non-driver initiated movements;

the RMS average of the magnitude of the non-driver initiated movements;

the number of peaks of the non-driver initiated movements per unit time.

Alternatively or additionally extent may involve one or more additional parameters. The term "magnitude" as used in the present application may refer to the amount of movement, irrespective of whether that movement is linear movement, angular movement or a combination thereof. Additionally, the term "magnitude" as used in the present application may also refer to a mathematical combination of the movement and another parameter, such as the vehicle speed.

The "THRESHOLD" lines shown in Figs. 1A and 1B define a predetermined relationship between driver initiated movements and non-driver initiated movements and shows the minimum extent of the driver initiated movements expected for the corresponding extent of non-driver initiated movements, which may be typically measured for a series of alert drivers or, alternatively may be typically established for specific alert drivers.

In practice, the threshold is preferably determined by correlating a statistically valid sampling of the results of the measuring the driver alertness, see for example the data presented in Fig. 5, with acceptable levels of driver alertness as measured by external means, such as visual records of the appearance of the driver or outputs of various biometric sensors. In setting the threshold, typically care is taken not to provide false alarms unnecessarily, which would result in driver dissatisfaction and refusal to use the system. In practice, a threshold is determined or selectable, which does not fail to provide an alarm when the driver is not sufficiently alert.

Turning to Fig. 1A, it is appreciated that operation of a motor vehicle by an alert driver is preferably characterized in that for at least a predetermined majority of a multiplicity of different time periods, a metric of the extent of driver initiated movements at least equals a corresponding metric of the extent of non-driver initiated movements.

Fig. 1B shows that corresponding operation of a motor vehicle by an non-alert driver is preferably characterized in that for at least a predetermined majority of a multiplicity of different time periods, a metric of the extent of driver initiated movements does not at least equal a corresponding metric of the extent of non-driver initiated movements.

Thus, it may be understood that, for example, when a driver is alert, as the magnitude of non-driver initiated motions increases, the frequency of occurrence of driver initiated motions should increase generally correspondingly.

Reference is now made to Fig. 2, which is a simplified pictorial illustration of a steering assembly and part of a chassis of a typical motor vehicle, illustrating a plurality of locations therealong where measurements of motion may be made in accordance with a preferred embodiment of the present invention.

In the motor vehicle shown in Fig. 2 and designated generally by reference numeral 100, there is provided a conventional steering assembly 102, including a steering wheel 104, a steering wheel shaft 106, connecting the steering wheel to a power steering unit 108, as well as right and left linkages 110 and 112 which connect the power steering unit to road wheels 114 and 116, respectively.

It is appreciated that the present invention may also be used with motor vehicles, which do not include a power steering unit 108.

In accordance with a preferred embodiment of the present invention, a driver alertness determining system is provided including a computation unit 120 which receives inputs from one or more angular motion sensors, preferably including a first angular motion sensor 122 disposed adjacent steering wheel shaft 106 at the steering wheel side thereof, a second angular motion sensor 124 disposed adjacent steering wheel shaft 106 at the power steering unit side thereof, a third angular motion sensor 126 disposed adjacent one of linkages 110 and 112, a fourth angular motion sensor 128 disposed adjacent a road wheel 114 or 116 and an acceleration sensor 130 mounted on a chassis portion 132 thereof.

Computation unit 120 also preferably receives an input from a vehicle speed sensor 134 and provides a driver sensible output via a driver alertness alarm 136, which may be any suitable alarm such as a tactile, visual, audio or audiovisual alarm.

As will be described hereinafter in detail, preferably inputs are received from two of the angular motion sensors, one adjacent the road wheels and one adjacent the steering wheel. Alternatively or additionally, an input from the acceleration sensor 130 in combination with one or more inputs from angular motion sensors may be employed.

Reference is now made to Fig. 3A, which is a simplified flow chart illustrating the functionality of Figs. 1A and 1B in accordance with one preferred embodiment of the present invention. As seen in Fig. 3A, data from a road wheel influenced displacement sensor, such as either of sensors 126 and 128, is normalized, at block 200, preferably to eliminate variations in measurements resulting from differences in the magnitudes of motion sensed by different sensors. Typical normalized data from the road wheel sensor 128 (Fig. 2) as a function of time, appear as a solid line in trace A1 of Fig. 4A, trace B1 of Fig. 4B and trace C1 of Fig. 4C.

It is appreciated that the term "displacement" as used throughout may, where suitable, refers to either or both of linear and angular displacements. In the case of steering wheel motion, the sensed displacement is angular displacement. In the case of road wheel displacement, either or both of angular displacement of the road wheel itself and linear displacement of elements coupled thereto may be sensed.

The output of block 200, is then filtered, at block 202, to remove noise, which in this case preferably includes all signal components having frequencies in

excess of approximately 10 Hz. Typical normalized and filtered data from the road wheel sensor 128 (Fig. 2) as a function of time, appear as a solid line in trace A2 of Fig. 4A, trace B2 of Fig. 4B and trace C2 of Fig. 4C.

The output of block 202 is split into high and low frequency components, preferably above and below 4 Hz, as indicated in block 204. The high frequency component of typical normalized and filtered data from the road wheel sensor 128 (Fig. 2) appears as trace A3 of Fig. 4A, trace B3 of Fig. 4B and trace C3 of Fig. 4C. The low frequency component of typical normalized and filtered data from sensor 128 (Fig. 2) as a function of time, appear as a solid line in each of trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C.

It is appreciated that the high frequency component, namely, the component above 4 Hz, is typical of the non-driver initiated movements. However, the component below 4 Hz may include both driver initiated movements and non-driver initiated movements.

The high frequency component output of block 204 is further processed, together with the data of the vehicle sensor 134 (Fig. 2), as indicated in a block 206, to further characterize this component. The functionality of block 206 may include one or more of calculating RMS values, average values, and standard deviations of the high frequency component, typically coupled with the data from the vehicle speed sensor 134 (Fig. 2), over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The output of block 206 is employed to determine the extent of non-driver initiated motion, as indicated in a block 208.

The low frequency component output of block 204 is further processed as indicated in a block 210, as is described hereinbelow.

Data from a steering wheel influenced angular displacement sensor, such as either of sensors 122 and 124, is normalized, at block 212, preferably to eliminate variations in measurements resulting from differences in the magnitudes of the motion sensed by different sensors. Typical normalized data from the steering wheel sensor 122 (Fig. 2) as a function of time, appear as a dashed line in trace A1 of Fig. 4A, trace B1 of Fig. 4B and trace C1 of Fig. 4C.

The output of block 212, is then filtered, at block 214, to remove noise,

which in this case preferably includes all signal components having frequencies in excess of approximately 10 Hz. Typical normalized and filtered data from the steering wheel sensor 122 (Fig. 2) as a function of time, appear as a dashed line in trace A2 of Fig. 4A, trace B2 of Fig. 4B and trace C2 of Fig. 4C.

The output of block 214 is preferably supplied to block 210, which is operative to determine the sign of the phase difference between the output of block 214 and the output of block 204, which are respectively represented by the dashed and solid lines in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C for each of a multiplicity of discrete time durations. This phase difference is defined to be positive, when the output of block 214, representing the steering wheel influenced motion, leads the output of block 204, representing the low frequency component of the road wheel influenced motion.

There exist various known techniques for determining the phase difference, any suitable one of which may be employed herein. The particular technique employed does not form part of the present invention.

When the phase difference is positive the relevant time duration to which that data relates is indicated, at block 216, to be driver initiated motion duration, indicated by a relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. The data representing driver initiated motion is then analyzed, at block 218, typically to determine the frequency of occurrence of driver initiated motions, which is an indication of the extent of driver initiated motions. Alternatively or additionally to determining the frequency of occurrence of driver initiated motions, any other suitable metric of the extent of driver initiated motions may be employed.

The frequency of occurrence of driver initiated motions may be determined by counting the number of extrema points in the dashed line appearing in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C during the driver initiated motion durations corresponding to the relatively thick lines in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. These extrema points are indicated by circles drawn on the relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C.

When the phase difference is negative, the relevant time duration to which that data relates is indicated, at block 220 to be non-driver initiated motion

duration, indicated by a relatively thin line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. The data representing non-driver initiated motion is then analyzed, at block 222, in order to further characterize this data. The functionality of block 222 may include one or more of calculating RMS values, average values, and standard deviations of the low frequency component, typically coupled with the data of the vehicle speed sensor (Fig. 2), over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The output of block 222 is supplied to block 208 along with the output from block 206 in order to determine the extent of non-driver initiated motion. The functionality of block 208 may be summarized as providing a metric indicating the level of non-driver initiated motion over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The level of non-driver initiated motion may be expressed in a number of possible ways, such as a linear or non-linear combination of low frequency and high frequency data, which reflects one or both of magnitude of such motion and frequency of direction change of such motion. Preferably, a linear combination of the low frequency and high frequency data is employed and reflects both magnitude and frequency of direction change.

The outputs of blocks 208 and 218 are employed in a block 224 to determine whether a driver meets alertness criteria, as will be described hereinbelow with reference to Figs. 5 and 6.

Reference is now made to Fig. 3B, which is a simplified flow chart illustrating the functionality of Figs. 1A and 1B in accordance with another preferred embodiment of the present invention. Generally speaking, the embodiment of Fig. 3B differs from that of Fig. 3A in that the embodiment of Fig. 3B does not separate or separately employ the high frequency portion of the output of a road wheel displacement sensor.

As seen in Fig. 3B, data from a road wheel influenced displacement sensor, such as either of sensors 126 and 128, is normalized, at block 300, preferably to eliminate variations in measurements resulting from differences in the magnitudes of motion sensed by different sensors. Typical normalized data from the road wheel sensor 128 (Fig. 2) as a function of time, appear as a solid line in trace A1 of Fig. 4A, trace B1

of Fig. 4B and trace C1 of Fig. 4C.

The output of block 300, is then filtered, at block 302, to remove noise and other irrelevant data, which in this case preferably includes all signal components having frequencies in excess of approximately 4 Hz. Typical normalized and filtered data from the road wheel sensor 128 (Fig. 2) as a function of time, appear as a solid line in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C.

The output of block 302 is further processed as indicated in a block 310, as is described hereinbelow.

Data from a steering wheel influenced angular displacement sensor, such as either of sensors 122 and 124, is normalized, at block 312, preferably to eliminate variations in measurements resulting from differences in the magnitudes of motion sensed by different sensors. Typical normalized data from the steering wheel sensor 122 (Fig. 2) as a function of time, appear as a dashed line in trace A1 of Fig. 4A, trace B1 of Fig. 4B and trace C1 of Fig. 4C.

The output of block 312, is then filtered, at block 314, to remove noise, which in this case preferably includes all signal components having frequencies in excess of approximately 4 Hz. Typical normalized and filtered data from sensor the steering wheel 122 (Fig. 2) as a function of time, appear as a dashed line in trace A2 of Fig. 4A, trace B2 of Fig. 4B and trace C2 of Fig. 4C.

The output of block 314 is preferably supplied to block 310, which is operative to determine the sign of the phase difference between the output of block 314 and the output of block 302, which are respectively represented by the dashed and solid lines in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C for each of a multiplicity of discrete time durations. This phase difference is defined to be positive, when the output of block 314, representing the steering wheel influenced motion, leads the output of block 302, representing the road wheel influenced motion.

There exist various known techniques for determining the phase difference, any suitable one of which may be employed herein. The particular technique employed does not form part of the present invention.

When the phase difference is positive, the relevant time duration to which that data relates is indicated, at block 316, to be driver initiated motion duration, indicated by a relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace

C5 of Fig. 4C. The data representing driver initiated motion is then analyzed, at block 318, typically to determine the frequency of occurrence of driver initiated motions, which is an indication of the extent of driver initiated motions. Alternatively or additionally to determining the frequency of occurrence of driver initiated motions, any other suitable metric of the extent of driver initiated motions may be employed.

The frequency of occurrence of driver initiated motions may be determined by counting the number of extrema points in the dashed line appearing in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C during the driver initiated motion durations corresponding to the relatively thick lines in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. These extrema points are indicated by circles drawn on the relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C.

When the phase difference is negative, the relevant time duration to which that data relates is indicated, at block 320 to be non-driver initiated motion duration, indicated by a relatively thin line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. The data representing non-driver initiated motion is then analyzed, at block 322, in order to further characterize this data. The functionality of block 322 may include one or more of calculating RMS values, average values, and standard deviations of the low frequency component, typically coupled with the data of the vehicle speed sensor 134 (Fig. 2), over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The output of block 322 is supplied to block 308 in order to determine the extent of non-driver initiated motion. The functionality of block 308 may be summarized as providing a metric indicating the level of non-driver initiated motion over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The level of non-driver initiated motion may be expressed in a number of possible ways, such as a linear or non-linear combination of data, which reflects one or both of magnitude of such motion and frequency of direction change of such motion. Preferably, a linear combination of the data is employed and reflects both magnitude and frequency of direction change.

The outputs of blocks 308 and 318 are employed in a block 324 to

determine whether a driver meets alertness criteria, as will be described hereinbelow with reference to Figs. 5 and 6.

Reference is now made to Fig. 3C, which is a simplified flow chart illustrating the functionality of Figs. 1A and 1B in accordance with still another preferred embodiment of the present invention. Generally speaking, the embodiment of Fig. 3C differs from that of Fig. 3A in that data from an accelerometer, such as the lateral component of data from an acceleration sensor 130 (Fig. 2) fixed to the chassis of a vehicle, is employed instead of data from a road wheel influenced displacement sensor. It is appreciated that as a further alternative, the data from both a road wheel influenced displacement sensor and from an accelerometer may be employed. It is also appreciated that a vertical component from an accelerometer may be employed to represent non-driver initiated motion.

As seen in Fig. 3C, data from an accelerometer, such as acceleration sensor 130, is normalized, at block 400, preferably to eliminate variations in measurements resulting from differences in the magnitudes and dimensions of motions sensed by different sensors. Typically, the normalized data from the lateral component of the output of acceleration sensor 130 (Fig. 2) as a function of time, appear as a solid line in trace A1 of Fig. 4A, trace B1 of Fig. 4B and trace C1 of Fig. 4C.

The output of block 400, is then filtered, at block 402, to remove noise, which in this case preferably includes all signal components having frequencies in excess of approximately 10 Hz. Typical the normalized and filtered data from the lateral component of the output of acceleration sensor 130 (Fig. 2) as a function of time, appear as a solid line in trace A2 of Fig. 4A, trace B2 of Fig. 4B and trace C2 of Fig. 4C.

The output of block 402 is split into high and low frequency components, preferably above and below 4 Hz, as indicated in block 404. The high frequency component of typical normalized and filtered data from the lateral component of the output of acceleration sensor 130 (Fig. 2) as a functions of time, appear as trace A3 of Fig. 4A, trace B3 of Fig. 4B and trace C3 of Fig. 4C. The low frequency component of typical normalized and filtered data from the lateral component of the output of acceleration sensor 130 (Fig. 2) as a function of time, appear as a solid line in each of trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C.

The high frequency component output of block 404 is further processed,

typically with the data from the vehicle speed sensor 134 (Fig. 2), as indicated in a block 406, to further characterize this component. The functionality of block 406 may include one or more of calculating RMS values, average values, and standard deviations of the high frequency component, typically with the data from the vehicle speed sensor 134 (Fig. 2), over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C. Optionally, a vertical component of the output of acceleration sensor 130 may also be employed in block 406.

The output of block 406 is employed to determine the extent of non-driver initiated motion, as indicated in a block 408.

The low frequency component output of block 404 is further processed as indicated in a block 410, as is described hereinbelow.

Data from a steering wheel influenced angular displacement sensor, such as either of sensors 122 and 124, is normalized, at block 412, preferably to eliminate variations in measurements resulting from differences in the magnitudes of motion sensed by different sensors. Typical normalized data from the steering wheel sensor 122 (Fig. 2) as a function of time, appear as a dashed line in trace A1 of Fig. 4A, trace B1 of Fig. 4B and trace C1 of Fig. 4C.

The output of block 412, is then filtered, at block 414, to remove noise, which in this case preferably includes all signal components having frequencies in excess of approximately 10 Hz. Typical normalized and filtered data from the steering wheel sensor 122 (Fig. 2) as a function of time, appear as a dashed line in trace A2 of Fig. 4A, trace B2 of Fig. 4B and trace C2 of Fig. 4C.

The output of block 414 is preferably supplied to block 410, which is operative to determine the sign of the phase difference between the output of block 414 and the output of block 404, which are respectively represented by the dashed and solid lines in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C for each of a multiplicity of discrete time durations. This phase difference is defined to be positive, when the output of block 414, representing the steering wheel influenced motion, leads the output of block 404, representing the low frequency component of the road wheel influenced motion.

There exist various known techniques for determining the phase difference, any suitable one of which may be employed herein. The particular technique

employed does not form part of the present invention.

When the phase difference is positive, the relevant time duration to which that data relates is indicated, at block 416, to be driver initiated motion duration, indicated by a relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. The data representing driver initiated motion is then analyzed, at block 418, typically to determine the frequency of occurrence of driver initiated motions, which is an indication of the extent of driver initiated motions. Alternatively or additionally to determining the frequency of occurrence of driver initiated motions, any other suitable metric of the extent of driver initiated motions may be employed.

The frequency of occurrence of driver initiated motions may be determined by counting the number of extrema points in the dashed line appearing in trace A4 of Fig. 4A, trace B4 of Fig. 4B and trace C4 of Fig. 4C during the driver initiated motion durations corresponding to the relatively thick lines in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. These extrema points are indicated by circles drawn on the relatively thick line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C.

When the phase difference is negative, the relevant time duration to which that data relates is indicated, at block 420 to be non-driver initiated motion duration, indicated by a relatively thin line in trace A5 of Fig. 4A, trace B5 of Fig. 4B and trace C5 of Fig. 4C. The data representing non-driver initiated motion is then analyzed, at block 422, in order to further characterize this data. The functionality of block 422 may include one or more of calculating RMS values, average values, and standard deviations of the low frequency component, typically with the data from the vehicle speed sensor 134 (Fig. 2), over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The output of block 422 is supplied to block 408 along with the output from block 406 in order to determine the extent of non-driver initiated motion. The functionality of block 408 may be summarized as providing a metric indicating the level of non-driver initiated motion over successive time periods, three of which are represented by respective Figs. 4A, 4B and 4C.

The level of non-driver initiated motion may be expressed in a number of possible ways, such as a linear or non-linear combination of low frequency and high

frequency data, which reflects one or both of magnitude of such motion and frequency of direction change of such motion. Preferably, a linear combination of the low frequency and high frequency data is employed and reflects both magnitude and frequency of direction change.

The outputs of blocks 408 and 418 are employed in a block 424 to determine whether a driver meets alertness criteria, as will be described hereinbelow with reference to Figs. 5 and 6.

It is appreciated that in the embodiments of Figs. 3A and 3B, the output of acceleration sensor 130 may be employed in place of or in addition to the output of a road-wheel influenced angular displacement sensor.

Reference is now made to Figs. 5 and 6, which illustrate utilization of determinations of extent of driver initiated and non-driver initiated motions for determining driver alertness. Typically, the Threshold Line is initially determined as discussed hereinabove (step 600, Fig. 6).

Preferably, as seen in Fig. 5, for each given time period, such as the three time periods represented by Figs. 4A, 4B and 4C, the extent of driver initiated motion and the extent of non-driver initiated motion are plotted in "Extent Space" (step 602, Fig. 6). Each such time period is represented by a single point in "Extent Space". Thus it may be seen in Fig. 5, that a point 550 represents the extent of driver initiated motion and the extent of non-driver initiated motion for the time period represented by Fig. 4A.

In the embodiments of Figs. 3A, 3B and 3C, the extent of driver initiated motions is preferably derived from the frequency of their occurrence, as exemplified by the number of circles appearing in traces A5, B5 and C5, respectively in Figs. 4A, 4B and 4C.

In the embodiments of Figs. 3A and 3C, the extent of non-driver initiated motions is preferably derived from the amplitude of the high frequency component of the non-driver initiated motions, as exemplified by the amplitudes appearing in traces A3, B3 and C3, typically combined with the amplitude of the low frequency component of the non-driver initiated motions taken together with other data relating thereto, such as the frequency of occurrence.

In the embodiment of Fig. 3B, the extent of non-driver initiated motions is preferably derived from the amplitude of the low frequency component of the

non-driver initiated motions taken together with other data relating thereto, such as the frequency of occurrence.

Referring again to Fig. 5, point 560 represents the extent of driver initiated motion and the extent of non-driver initiated motion for the time period represented by Fig. 4B and point 570 represents the extent of driver initiated motion and the extent of non-driver initiated motion for the time period represented by Fig. 4C.

Similar plots in Figs. 1A and 1B represent the extent of driver initiated motion and the extent of non-driver initiated motion for a relatively large number of time periods.

As seen in Figs. 1A, 1B and 5, there appears a threshold line that differentiates couples of the extent of driver initiated motion and the extent of non-driver initiated motion for a given time period and being characteristic of driver alertness (above the line) and non-alertness (below the line).

In reality, this threshold line may be fixed or variable as the result of variations in one or more parameters, including, inter alia, vehicle speed, elapsed duration of trip, known or earlier determined driving characteristics of the driver, travel conditions and type of vehicle.

A determination of driver alertness or non-alertness may be a cumulative determination based on a weighting of the points appearing above and below the threshold line, once a statistically acceptable sample is achieved (steps 604 and 606, Fig. 6). Alternatively or additionally, it may be a determination based on the change in the position of successive points relative to the threshold line and relative to each other as time passes.

Based on the determination of driver alertness or non-alertness made from time to time, an appropriate alarm indication is provided to the driver (step 608, Fig. 6), preferably via alarm 136 (Fig. 2).

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove as well as variations and modifications which would occur to persons skilled in the art upon reading the specification and which are not in the prior art.